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A POPULAR
MINERALOGY
AND
GEOLOGY.

Prepared from the latest and best authorities in Europe and America.

BY

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ILLUSTRATIONS.

The Earth in its Nebulous State.
Mount Vesuvius.
Geyser.
Metallic Vein.
Coral Islands.
Glacier.
Devonian Fish.
Plants of the Coral Measures.
Reptiles (3).
Mammals (3).

AUTHORITIES CONSULTED.

Barrande.
Bunsen.
Dana.
Figuier.
Geikie.
Hayden.
Hopkins.
Huxley.
Liebig.
Le Conte.
Lyell.
Murchison.
Newberry.
Owen.
Roscoe.
Thomson, Sir William
Tyndall.

For the engravings the author is indebted to the French of M. Figuier, except in the case of the *Geyser*, which, by the courtesy of Messrs. Appleton & Co., was taken from *Le Conte's Geology*.

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PREFACE.

As its title expresses, this little book is an outline of the history of the earth, from its creation up to the present time.

The structure of our planet is explained as well as the action of the agents—air, water and heat—that have made it assume its present appearance.

The successive forms of life are taken up, and their most striking characteristics pointed out. We have also considered the causes, so far as known, that lead to their extinction or modification.

Thus we say that the invertebrates and fishes first appeared, because the lately cooled earth was incapable of supporting any higher forms of life. Next, that the coal-measures were laid down, because in certain localities the nature of the soil and the superabundance of carbonic acid in the atmosphere rendered possible a rank vegetable growth whose decay made the coal.

The partial exhaustion of carbonic acid made the air more fit for breathing, and reptiles were introduced.

Then, the conditions being favorable, mammals—the highest form of life—appeared on the scene.

We know that, owing to causes about which the scientists still dispute, this gradual progression stopped. The mammals, with every other form of life, were almost all swept away by the desolation of the *Ice Age.*

Those that escaped death were driven far to the south, till, the rigor of the arctic climate having abated, a slow migration northward again took place.

The mammals having re-established themselves, some of them developed into brutes of extraordinary size, and some into brutes of extraordinary ferocity.

Man is the last to appear, and weak as an infant in comparison with the animals about him, yet he, by his intelligence, exterminates the monsters, or tames them, and makes them the servants of his will.

This part of the history cannot fail to be of the highest interest. The only regret is, that the limits of the book forbid its being anything more than a mere sketch.

The minerals, of which the rocks are composed, are also briefly described.

It would be a great advantage to the children if in every school there were a collection of at least twenty common minerals, plainly labeled. The pupils should then be encouraged to make collections for themselves, verifying their *guesses* by comparison with the labeled specimens. Thus an interest in the mineral kingdom will be awakened in the child's mind. He will not forget what he learns in this way; there is a fascination about it; he has collected the stones himself, compared them with the specimens in the class-room, and *knows* if they are or are not of the same kind.

He has learned by doing.

THE AUTHOR.

EARTH IN NEBULOUS CONDITION.

IN THE BEGINNING.

"In the beginning God created the heavens and the earth, and the earth was without form and void; and darkness was on the face of the deep."

This is the sentence with which the Biblical account of the creation opens.

The modern scientist says the same thing in different words.

"In the beginning one great mass of nebulous matter filled all space." By nebulous matter he means a cloudy or gaseous body, infinitely thin. By means of a telescope we can see such nebulous matter surrounding some of the heavenly bodies, and it looks like a mass of very light, slightly luminous clouds.

This mass of matter, launched forth by the hand of the Creator, revolved in space, and as it revolved the outer portions separated from the center. The separated part then appeared as a *ring*, revolving in the same direction as before.

* The ring finally broke, however, and then its particles, falling together, a *sphere* was formed, which, keeping up its original motion, became a satellite of the parent mass.

"In this way the planets were formed which revolve around the sun, and by a secondary process, the *moon*, which revolves around the earth."—*La Place.*

Besides the revolution around the sun each planet rotates on its own axis.

By the law of gravitation all bodies are drawn or attracted toward the center, and in obedience to this law the particles of our earth were gradually condensed. The gaseous mass became liquid, or at least plastic.

The *space* through which this mass of liquid metals and gases revolved was cold, intensely cold—200 degrees below zero.

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* In the planet Saturn the ring is still visible.

The fiery globe turning around in the cold space gradually cooled on the outside, and a thin crust was formed. But this thin crust was constantly being broken through by the liquid mass inside, which poured over it, buried it, and then in turn became itself a crust.

How long this war between the thin crust and the liquid interior lasted no one can tell, but it ceased at last. The crust became thicker. The molten mass broke through more rarely.

The atmosphere was still quite unlike the present. It was rank with carbonic acid, and held as vapor all the waters now on the face of the earth. Through such an atmosphere the rays of the sun could not penetrate.

When the surface became cool enough to permit the vapor to assume the liquid form, it fell as rain. But the rain itself was hot, and it fell on the still heated rocks. The consequence was that it instantly flashed into steam and rushed back again through the atmosphere.

But that war, too, ended. The water remained water, and rested where it fell. No doubt the whole surface of the earth was for a long time covered with a shallow sea.

The uneasy interior manifested itself by upheavals and depressions of the crust, and the water gradually drew off into the depressed parts. This was the beginning of the ocean basins.

"During this primitive epoch the temperature of the earth was much too high to permit of the appearance of living beings on its surface. The darkness of night concealed the birth of the world; the atmosphere, in short, was so charged with vapors of various kinds that the sun's rays were powerless to pierce its opacity. Upon this burning soil, and in this continuous night, organic life could not maintain itself. No plant, no animal, then could exist upon the silent earth, and in the seas of the period are deposited only unfossiliferous strata."—*Figuier*.

But by degress, very, very slow degrees, the earth became fit to support organisms.

As might be expected, the first forms of life were low in the scale.

The conditions were not suitable for complicated organizations.

Thus the first plants were sea-weeds, and the first animals invertebrates—animals without a back-bone.

We learn the order of the appearance of life from the strata under our feet, and thus the rocks are a stony book in which we find recorded every stage of progress in plant and animal life from the most obscure beginning till the time when flower and fruit appeared in the vegetable world, and man, the lord of all, in the animal.

Then the cycle of created things was complete. Then the Creator ceased from his labors and said:

"It is good."

EARTHQUAKES.

As we have said, the atmosphere finally won in its struggle against the fiery interior. The outside crust became so hard that the fire could no longer melt it, break it up, or overflow it. Then the fire demon retreated deeper and deeper into the bowels of the earth, and there he still remains. However, he keeps a road open to the upper world—many roads rather. We call them *volcanoes*. Sometimes he playfully or fearfully spurts forth the liquid rock from these orifices; but sometimes, remembering his former greatness, he roars and writhes within his rocky walls, till, like the furious demon of the story, he becomes endowed with the strength of ten demons. Then the earth trembles, mountains are rent asunder, the sea rises high and rushes over the affrighted land. Then, as the fierce waters sullenly retire, ships are found stranded on the shores, proud cities have disappeared from the face of the earth, engulfed in the horrible chasms that opened in their midst, or buried under the floods of burning lava poured forth from some volcano.

This is no imaginary picture. In the great Lisbon earthquake of 1755 a wave sixty feet high washed over the doomed city, completing the destruction begun by the tremblings of the earth. In 1819 an earthquake shook the region about the mouth of the Indus. When it had passed it was found that two thousand square miles of territory had been sunk beneath the neighboring surface. The Naples earthquake of 1857 killed ten thousand people. At Riobamba (1797) the shock was like the explosion from a mine. Objects were thrown upward with tremendous force. "Bodies of men were hurled hundreds of feet into the air, and were afterwards found across rivers or on the tops of hills."—*Le Conte.*

The explanation of earthquakes, as given by most scientists, is as follows: The interior of the earth is a mass of fiery, liquid rock. The portions of this molten mass that are closest to the crust becomes cooler, and in cooling *contract.* The solid crust, trying to adjust itself, contracts also. (*Le Conte* says there is a *constant* unnoticed contraction taking place.) If the contraction takes place violently, the earth is rent. We have the earthquake.

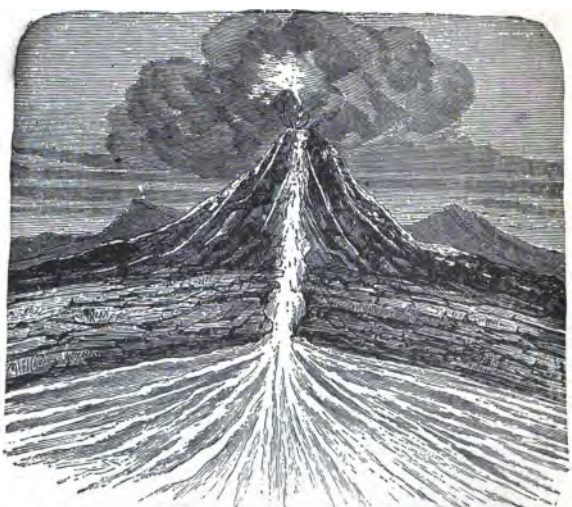
Another explanation is, that the quaking is caused by the sudden formation or sudden collapse of immense quantities of vapor or gas in fissures of the crust.

In all explanations of such phenomena as earthquakes, it must be borne in mind that only *theories* are given. No man knows absolutely the cause of an earthquake, nor can tell its probable duration or force. As an example of this it is only necessary to say, that according to *Sir William Thomson* the earth is *solid to the center.* There is no mass of liquid rock in the interior. Volcanoes are merely *local* eruptions from some local cause. In proof of this statement, this scientist says that if the earth were liquid at the center it would be affected by the sun and moon just as the tides are; whereas, as a matter of fact, our globe is no more influenced by the sun and moon than if it were a globe of solid glass.

According to *Mallet,* who has collected records of upwards of seven thousand earthquakes, they average about two a week. As many earthquakes occur under the bed of the sea, and in deserts, where there is none to record them, it is no doubt correct to say that the earth's crust is never at rest.

Between earthquakes and volcanoes there is a close, though not well understood, connection. Great eruptions from the latter are often accompanied by the former. Again, rumblings and quakings often cease when the volcano begins to vomit forth its lava, and the cessation of the eruption is often followed by violent shocks. This is particularly the case along the uneasy sides of the Andes. Travelers say that the people watch Cotopaxi, knowing by fearful experience that when the wreath of smoke disappears from the mountain, the deadly shock is at hand.

VESUVIUS IN ACTION.



SECTION OF VOLCANO.

VOLCANOES.

A volcano is a mountain having an opening called a crater, through which the lava escapes. The crater is cup-shaped. In the quieter kinds the bottom of the cup melts. Then the lava boils and bubbles like any fluid, and overflows the edge. In sudden eruptions the bottom of the cup is blown violently out, scattering in all directions fragments of rock, ashes, cinders and steam. An immense amount of stifling gas is also driven out, and continues to escape long after the lava has ceased to flow.

In the violent kind the explosions are often heard miles away. According to *Lyell*, the explosions at Tomboro, near Java, in 1815, were heard at Sumatra, nine hundred and seventy miles distant. In this dreadful visitation, so sudden and overwhelming was the eruption, that out of a population of twelve thousand souls only twenty-six remained alive.

The crater of a volcano has been called a cup, but it would be more correct to call it a pipe, with the lower end closed when not in action. The pipe or tube extends downward into the bowels of the earth, no one knows how deep. It may reach the molten mass of the interior, and serve as a funnel for its escape. If, as *Hopkins* and *Thomson* affirm, this is no molten interior, then the lava must come from some local reservoir of melted rock.

Volcanoes are generally found near the sea, often on islands. There are many volcanic islands in the Pacific. The supposition is that those islands began as volcanoes beneath the sea, and have gradually grown up to the surface. In the Mediterranean new islands have been formed under the eyes of observers.

In some of the more violent eruptions the loss of life has been great. The most memorable, perhaps, was that of Mount Vesuvius, which buried Herculaneum and Pompeii.

Although we speak of the *smoke* about the crater of a volcano, there is no real smoke, for that would imply combustion, and, of course, there is no combustion. What is popularly termed smoke consists of vapors more or less condensed. The *flame* is the red glare from the fiery lava.

Whatever the crater may open into, the immediate *cause* of the eruption is the same. Water percolating through fissures in the crust of the earth comes in contact with superheated strata. The water is immediately changed into steam, and the immense pressure power of the steam ejects the lava. The power of the steam may be imagined on considering that at Cotopaxi a rock mass of over two thousand seven hundred cubic feet was projected from the crater to a distance of nine miles. (*Lyell.*)

We speak of *active* volcanoes and of *extinct* volcanoes, but it is a difficult matter to say when a volcano really becomes extinct.

For ages the fires of Vesuvius were supposed to have gone out, never to be rekindled, yet, suddenly, in the year 79 of our era, the lava burst forth, burying the two doomed cities.

The volcano of *Stromboli* is a natural lighthouse. According to *Figuier*, its eruptions are continuous. The lava in the crater is always bubbling, and these bubbles, as they come to the surface, project upward tall columns of ashes. During the night these columns shine with a magnificent red reflection, lighting up the surrounding sea.

The volcano of *Kilauea*, Sandwich Islands, is one of the wonders of nature. The crater of this monster is an immense chasm a thousand feet deep, and its outer circuit from two to three miles in diameter.

In this lake the molten lava bubbles and boils, but instead of overflowing its borders it finds its way by a subterranean passage to the sea.

The volcanoes of Java and the neighboring islands are particularly violent. Forty-six craters have been counted in the mountains of Java alone. Of course every crater does not represent an actually erupting volcano, but many of the so-called extinct ones are quite as dangerous as when active, owing to the gases which they emit.

"The last phase of volcanic activity is the disengagement of carbonic acid gas. This deadly emanation is the gas that fills the Valley of Poison—a place of horror to the natives of Java. In this renowned valley the soil is covered with the skeletons of tigers, stags, birds, and men, for asphyxia or suffocation strikes all living things that venture into the place."—*Figuier*.

It is this same gas that fills the *Grotto del Cane*, near Naples. In the Italian death-trap, however, the carbonic acid gas does not rise to any considerable height, consequently man may walk through it with safety, while the dog, running with his nose to the ground, is sure to be overpowered.

Grotto del Cane means Dog's Grotto. The name originated from the fact that dogs who ran into it were stifled by the deadly emanations near the surface.

GEYSERS.

A geyser is a spring, which, instead of affording a gentle constant flow of water, erupts, from time to time, violently, like a volcano. Between the times of erupting there is no flow of water at all.

According to *Bunsen*, who is considered the best authority on the subject, the geyser does not find a tube ready through which it may flow. On the contrary it makes its own tube. This is the way it does it:

The geyser, at first an ordinary hot spring, contains *silica* in solution. In cooling or drying, the silica is deposited about the sides of the spring, in a circle. More silica is deposited on the first layer, more on the second, and thus by degrees—almost inconceivably slow degrees to us—a tube is formed through which the water flows.

In order that a hot spring should become a geyser, the tube must be long. Just how long is not definitely known, but the Great Geyser (Iceland) has a funnel-shaped tube seventy-eight feet deep. This geyser has a basin or pool at its mouth which measures fifty-six feet in diameter. Both basin and pool are lined with silica which has been deposited from the water. When the geyser is not erupting, the basin is filled with clear water at about 175 degrees temperature.

The eruptions in this geyser occur every ninety minutes, and last about seven minutes. Before bursting forth, a noise like cannonading is heard beneath the water. This is caused by the bursting of the steam bubbles which form in the lower part of the tube and collapse on rising into the colder water above. Following the noise the water becomes violently agitated. Then in an instant it is shot upward one hundred feet, forming a magnificent fountain. Immediately after the water clouds of steam ascend with a roaring noise. The

GEYSER.

scene is repeated several times in quick succession, and then all is quiet for the next ninety minutes.

Bunsen explained their action in this way:

The rain falling on the surface of the ground, percolates through fissures in the rocks till it comes in contact with a layer which is impervious to water, and *along* which it is consequently obliged to flow. This subterranean river finally flows over a superheated stratum of rock which raises the temperature perhaps to the boiling point. The underground river, continuing its course, at length finds an opening through which it is enabled to again reach the surface. It is of course greatly aided in this by the *steam* which formed below near the heated rocks, and whose pressure now sends the water to the surface. If the water on its upward way has had to pass through many layers of cold rock, it bursts forth an ordinary cold water spring. If it has come to the surface through a *short* tube, or through no tube, if the point from which it started was not deep below the ground, then, though it may retain its heat, it is no geyser—merely a hot spring. To have the phenomenon of an *eruption* of hot water it is necessary that the water be confined in a tube. The heat at the bottom of the tube raises the temperature, evolving steam. The pressure of the steam tends to force the water out of the tube, but the pressure of the *atmosphere*—15 pounds to the square inch—tends to keep the water back. At a certain point the upward pressure of the steam becomes greater than the downward pressure of the air. Then the water is forced violently upwards, followed by immense volumes of steam, which, intermingling with the water, forms a spray of dazzling beauty. The display generally lasts from two to seven minutes, and is again repeated after a certain fixed time. The time, however, varies with each geyser.

"*Old Faithful*, in the Yellowstone Park, throws up a column of water six feet in diameter to a height of one hundred and fifty feet. It erupts every hour and plays fifteen minutes."—*Hayden*.

According to the same authority, the *Grand Geyser* shoots up a column two hundred feet high, and the *Bee Hive*, so called on account of the shape of the mound around the basin, sends up a splendid column to a height of two hundred and nineteen feet.

ARTESIAN WELLS.

Water forcing its way downward through the rocks is finally caught between two impervious strata. Held thus between two layers of rock the water is under great pressure, and if a boring is made from the surface down to this confined water, it will spout upward with great force at first. The *source* of such a well may be, and often is, many miles away from the spot where the boring has been made.

The reason why the artesian wells do not dry up is because they are constantly fed by the underground rivers that gave them birth; the rivers, of course, like surface rivers, being constant streams.

Some of these wells are very deep. There is one in Paris that has a depth of two thousand feet, and one in St. Louis nearly four thousand feet deep.

In dry countries nearly all the water for irrigating the soil is obtained from these wells.

RIVERS.

Some of the rain that falls to the ground flows off into the sea; some finds its way by underground channels to the same. Much of it, however, after passing through clefts in the rocks, and eating out the softer portions—limestone, etc.—re-appears at the surface in the form of *springs*. These springs are the beginnings of great rivers, the rivers that, after hundreds or even thousands of miles of tortuous windings, find their way inevitably to the ocean, the source from which they sprung.

All rivers fertilize the soil, and serve more or less as highways for commerce; but there are some that deserve special mention.

The *Nile*, famous in history as the stream on whose banks the great Egyptian civilization was unfolded, is remarkable, geologically, on account of its annual overflow, which, in the course of ages, has made the fertile soil of the country. This overflow is caused by the irruption into its waters of the swollen streams that feed it, thousands of miles away. On this overflow the very life of the peasant depends. If it should not be great enough his rice field will not yield sufficient grain to maintain himself and his children the coming year. Should the overflow be too great his miserable hut will be swept away. With hope and fear he watches the rising of the mighty stream, and with blessings or curses, according as it has served or ruined him, he sees it retire.

At the mouth of this famous river is the no less famous *delta*. This is a portion of land one hundred miles long and two hundred miles wide at its base. It represents an area which has been reclaimed from the sea, all being formed by sediment brought down by the river.

We know that the delta of the Rhone has advanced one and a half miles since the Roman occupation, for *Valais*, which then stood on the lake, is now a mile and a half inland.

The delta of the Mississippi is estimated at over twelve thousand square miles.

In the case of deltas we have land made by the rivers. In other instances it is the river, or rather the ocean, that destroys the land. If the river empties into a tidal sea, a *bay* is formed at its mouth. This is the case with all rivers emptying into the Atlantic. The bay is formed by the erosive action of the waves, the ebbing and flowing of the tides.

"From some obstructions at the mouth of the Amazon, the tide, instead of being a quiet rising, plunges in in the form of five or six huge waves from twelve to fifteen feet high.

In the Tsien-tang a single wave plunges along at the rate of twenty-five miles an hour, with perpendicular front like an advancing cataract, four or five miles wide and thirty feet high.

The erosive power of such currents must be immense."—*Le Conte.*

Erosive.—Wearing away the rocks by the action of water.

VEINS.

By movements of the earth's crust cracks or fissures are often formed, extending from the surface to unknown depths below. Sometimes, as during a violent earthquake, these fissures close again, but often they remain open, and are sooner or later filled with mineral matter. When filled with rock matter, these fissures are called *dikes*; when filled with metallic ores they are called *veins.*

Metalliferous veins are usually found in mountain regions. The lifting and folding together of the rocks, by which the mountains have been made, has caused the great fissures in which the metals are found.

To this rule, however, *lead veins* are an exception. These are found in perfectly level regions, which show no trace of ever having been disturbed. This is the case in the lead regions of Iowa, Missouri, and Illinois.

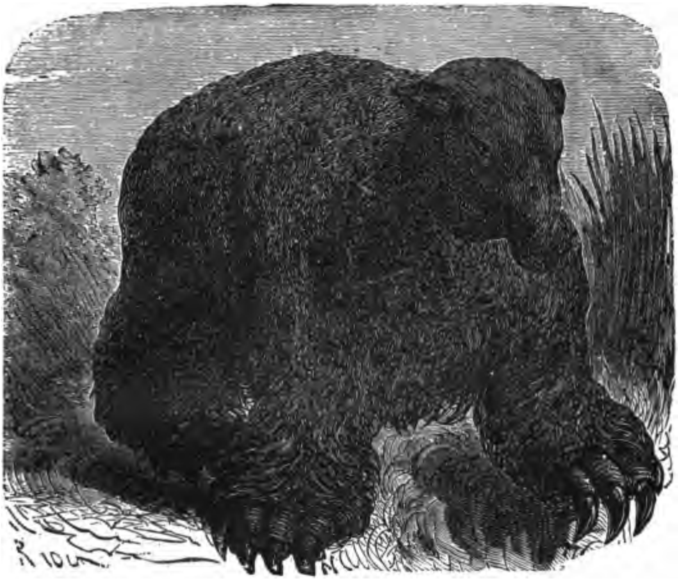
In the veins, gold and platinum are always found pure, that is, not *chemically* combined with any other substance.

Silver and copper are often found pure also, and occasionally other metals. Generally, however, metals are found as *ores*, that is, united chemically with some other substances.*

There are many theories to account for the presence of metals in veins. The one which, according to *Le Conte*, is the most probable, is, in outline, as follows:

Water percolating at great depths through the rocks becomes, of course, heated. Many substances which would dissolve very slowly, if at all, in cold water, dissolve very readily in presence of water at a high temperature. The

*Note.—Sugar and salt, stirred up together, form a *mixture*; both remain precisely what they were before. Oxygen and hydrogen, when united, form a chemical combination, the two gases making the liquid water.



MEGATHERIUM.

VEINS OF GRANITE THROUGH STRATIFIED ROCKS.

metallic ores have been thus dissolved, and have been carried with the water into the fissures of the rocks, where we now find them. The water which contained the ores in solution deposited them on cooling.

THE METALS.

GOLD.

Gold is found in grains, in threads, and in scales. It is found embedded in the hard quartz and among the loose gravel of ancient river beds.

In the rock, gold is associated with the sulphide of iron (*pyrites*). The action of the atmosphere partly dissolves the pyrites, and the gold is left exposed in grains throughout the quartz.

Lower down, beyond the reach of the atmospheric agencies, the gold remains locked up in the pyrites, and to obtain it the whole mass of quartz must be broken and ground.

The *placers* are the beds of ancient rivers whose waters swept along the gold bearing quartz mountain, wore away the hard rock, and deposited its fragments along their beds. The gold thus washed out being heavier than the rock, sank to the bottom, and now forms the rich placer mines.

Gold can be drawn out into very fine wire, and beaten into thin sheets. The atmosphere does not affect it. It is nearly as soft as lead, but is very heavy—nineteen times heavier than water. Our gold coin is an alloy of gold and copper.

The copper is mixed with the gold to harden it. All gold ornaments are made of an alloy of gold and copper in different proportions.*

SILVER.

Silver is often found native, that is, not chemically com-

* NOTE.—"Iron and copper pyrites are often mistaken for gold by the inexperienced. But the former are brittle, while gold may be cut in slices and flattened under the hammer."—*Dana.*

bined with any other substance, but it also forms many ores.

Silver is much used in the arts, and has been known in all historic times.

It is very ductile, and is the best conductor of heat and electricity known.

Silver combines readily with sulphur, and this is why silver articles tarnish on being long exposed to the air. The tarnish is the *sulphide* of silver.

"In the copper mines, about Lake Superior, masses and strings of pure silver are often found penetrating the copper." —*Dana*.

MERCURY.

Mercury is a fluid metal at ordinary temperature, but freezes at 40 degrees below zero. Hence, to measure degrees of temperature below that point other appliances have to be used.

Mercury is sometimes obtained in a pure state—in little pools that may be dipped up. But generally it comes as a sulphide. The metal is then obtained by burning off the sulphur.

It is found in Spain, Austria, Peru, and California.

The use of mercury in thermometers and barometers is familiar to every one. It is also employed in freeing gold and silver from their ores, in the manufacture of mirrors, and in medicine.

COPPER.

Copper is a metal of a reddish brown color. It is found pure and alloyed. It is malleable, ductile and tenacious. Does not rust in dry air, nor in moist at moderate temperatures.

Verdigris is the green film that forms on copper. It is poisonous, and for this reason cooking vessels made of copper should be carefully watched to see that the verdigris does not form. Copper is used as a sheathing for ships, and it has many uses in the arts.

Brass is an alloy of copper and zinc; *bronze* of copper and tin.

Mankind seems to have known the use of copper long before that of iron, as weapons and ornaments of copper are found almost with the earliest trace of man.

Copper forms ores with sulphur and iron. But where the vein comes to the surface there is usually found no copper at all. In fact, the miners must dig from thirty to sixty feet before they find any. This is because the action of the atmosphere has separated the copper from the other substances. The iron remains at the surface in a loose, spongy condition, and the copper sinks. Below the influence of the atmospheric agencies this copper is found native, and below that again it is found in its usual condition, that is, chemically united with iron and sulphur.

LEAD.

Lead is generally found in combination with sulphur (*Galena*).

Unlike most metals, lead occurs in great beds between layers of limestone, and not in veins. At the *outcrop*, where the metal comes to the surface, the sulphite is usually changed to a carbonate, but by following this the miner soon comes to the sulphite.

Lead furnishes the white lead and chrome yellow used by the painter, and lead acetate, sugar of lead, of the druggist.

The lead water pipe used by the plumber sometimes corrodes slightly, making the water poisonous.

TIN.

Tin is found in combination with other substances When freed it is used as a coating for other metals—iron particularly. It is much used in the arts, as it is not affected by the atmosphere. The tin mines of Britain were known to the ancients, and were worked more than four hundred years before the Christian era. Tin mines are found in Germany, Australia, and California.

Iron.—There are three principal ores of iron, *viz.:* limonite, hematite, and magnetite. The pure metal crystallizes in cubes. Steel is iron which has been made red hot in combination with charcoal. The process makes the *fibrous* texture of the iron become *granular*, hardens it but makes it brittle. Friction often has the same effect, the fibrous railway ties becoming granular, brittle, and then breaking, often with disastrous results.

The sulphate of iron furnishes green vitriol and sulphuric acid.

Limonite is one of the best known ores of iron. Its color varies from black to yellow. It contains water; is much used in manufactures. It is the yellow ochre of the painter.

Hematite, so called from a Greek word signifying blood, yields a red powder. The fine gray and black crystals of this ore show the same color when beaten into powder as do the red uncrystalline varieties.

"The Iron Mountains of Missouri consist mainly of this ore, piled in masses of all sizes, from a pigeon's egg to a middle-sized church."—*Dana.*

Magnetite, as its name implies, is magnetic iron ore. It is found massive and in crystals. When the magnet possesses the property of polarity it is called *lodestone.* Nearly all the iron in Sweden is magnetic. The same variety is found in New York, Missouri and California.

"Pure iron ore is found in southern Utah, standing above the surface of the country as mountain ridges, or like huge black walls one thousand feet long, five hundred feet thick, and rising in castellated crags two hundred to three hundred feet high."—*Newberry.*

THE CRUST OF THE EARTH.

When the earth began to cool from the incandescent state it formed a thin crust. This crust was constantly being broken through by the fiery mass inside. The thin crust being heavier than the interior, it would sink and melt again, and the overflowing rock matter would form the new crust.

But when the outside finally solidified, and the vapors had condensed into water, the action of this water immediately began to wear away the rock surface, to carry it from higher to lower levels, and there deposit it. Thus was formed the first layer of sedimentary rock. From that time to this the air and the water have never ceased to act on the surface rocks, breaking them down, carrying them away, and spreading them out, generally in form of gravel or mud, over other rocks.

If the earth had suffered no violent convulsions since its first cooling, nothing would be easier than to read its history in the positions of the rocks. The lowermost layer would then have been the first deposited, the next layer the second, and so on up to present time and rock layers now forming. As a matter of fact, however, the position of the rock strata gives little or no information as to relative age. Our planet has suffered so many and such extreme changes that it is by the *fossils* rather than by any other means, that we determine which are the oldest rocks.

The surface of our planet is very irregular. The lowest parts, the hollows, form the sea basins, and the most elevated portions form the mountains. The greatest land elevation is about five miles, and the deepest sea has a depth of about the same extent.

All the rocks forming the crust of the earth have been classified by geologists into stratified and unstratified.

The stratified rocks are those that have been deposited in water. They form successive layers, and contain *fossils*. The unstratified rocks are crystalline in structure, and have been formed by igneous agency.

"In geology the term *rock* is used to signify any material constituting a portion of the earth, whether hard or soft. Thus, a bed of sand or clay is no less a rock than the hardest granite. In fact, it is impossible to draw any scientific distinction between materials founded on hardness alone. The same mass of limestone may be soft chalk in one part and hard marble in another; the same bed of clay may be hard slate in one part and good brick earth in another; the same bed of sandstone may be hard grit in one place and soft enough to be spaded in another. The same volcanic material may be stony, glassy, scoriaceous, or loose sand or ashes."—*Le Conte.*

The stratified rocks are of three kinds, namely: sandstones, limestones and clays.

Sandstones consist of grains of sand (quartz) cemented together by carbonate of lime or oxide of iron. In the former case the sandstone is easily acted upon by the atmosphere, but when the cement is the iron oxide the stone is excellent for building purposes.

The base of all limestones is the metal calcium. Chalk and marble are carbonates of lime; gypsum and alabaster are sulphates of lime.

The clays are shales and slates.

All these rocks graduate into each other, and it is often difficult to say in what class a specimen belongs.

The *unstratified* rocks contain no fossils, are generally crystalline in structure, and instead of being spread out in layers, appear to have been thrust up violently through the stratified beds. *Igneous* is the usual name for the unstratified rocks.

The minerals which constitute the igneous rocks are principally quartz, feldspar, mica, hornblende, talc, and serpentine.

But these same minerals when ground up, carried by water and deposited in layers, form the *stratified* rocks.

Thus we see there is a constant circle of change going on in the mineral kingdom.

SANDSTONES.

Quartz, when crystalline, forms six-sided prisms. It is often massive, and is the chief constituent of *granite.*

When the crystals are colorless they are known as rock crystals; if yellow, as topaz; purple, amethyst. These are often of great beauty, and may be readily mistaken for real gems. Chalcedony is a handsome semi-transparent quartz found in various colors. Agate, onyx and flint are other well-known varieties.

Hornblende forms greenish black crystals; is also massive. One variety, asbestos, is fibrous, and may be woven like flax. It will not consume in fire. The emerald is a green crystalline silicate; the garnet a ruby red.

Mica forms thin scales, which are transparent and elastic. It is a constituent of granite. Is used in doors of stoves because it is not affected by heat, and permits the fire to shine through.

Feldspar, the third constituent of granite, varies in color from white to deep pink, sometimes with a tinge of green. When decomposed into clay, forms the porcelain of the arts.

Talc is foliated or crystalline. The color, from silver white to green. Feel, unctuous (oily). Soapstone and French chalk are varieties of talc. This mineral has the foliated structure of mica, but is not elastic.

Serpentine is a dark green, massive mineral. It takes a high polish, and is known as verd-antique marble.

LIMESTONE.

Limestone is very widely diffused in nature. Many mountains are made in part or entirely of this mineral. Wherever it is found, on tops of mountains, or on plains in middle of vast continents, we know in that place the sea once ebbed and flowed.

How do we know it?

Because every particle of lime is supposed to have once been part of some living animal, and wherever the stone is now found, whether a mere conglomerate of sea-shells or transformed into the finest marble, the man of science knows that sea animals once lived.

In some limestone the animal structure is still plainly visible, but in other varieties, such as marble, heat and pressure have so changed the original appearance that the rock has become crystallized.

The principal varieties, besides the common limestone of the quarry, are marble, chalk, gypsum, and alabaster. The last two are *sulphates* of lime, and the others are *carbonates*.

The common limestone is burned in a kiln to drive off the carbonic acid; the substance which remains is *lime*.

Gypsum is used as a fertilizer; alabaster is so soft that it may be cut with a knife. Every school-boy knows the use of chalk, though the crayons used in the class-room are not chalk, but a mixture of ground plaster (gypsum) and glue. The beautiful crystalline varieties of limestone, the marbles and spars, are carved into ornaments, or, in the case of marble, used for building purposes.

As the sea has at various times covered every inch of our globe, there is no part of it where limestone is not found. In certain places, however, the deposits are greater or more valuable. Greece and Italy furnish the finest statuary marble. The southern shores of England are correctly called the "Chalky Cliffs," being quite composed of that soft material. Our Eastern States furnish some good varieties of marble, besides immense quantities of what is known as limestone proper.

But it is not sea animals alone whose skeletons furnish lime—all animal skeletons contain it. The skeletons of air-breathing animals, however, are never huddled together in sufficient quantities to form cliffs and quarries.

CORALS.

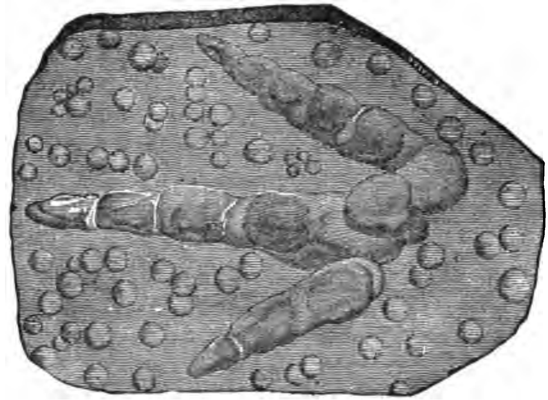
Of all the beautiful and wonderful works performed by instinct-guided animals there is nothing more beautiful or more wonderful than the work done by the atoms of life we call *coral polyps*.

The polyp, like the sponge, is attached to one spot during all its brief life. It has no power of locomotion. Wherever hazard has deposited the first egg, there the developed animal remains.

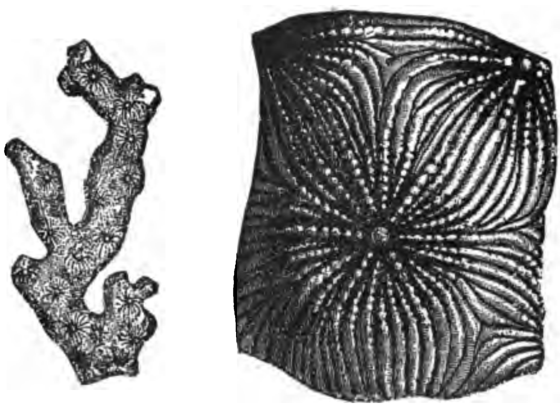
In appearance the coral polyp resembles a drop of jelly, and is generally not larger than the head of a pin. The animal has no fins, no proper head. There is an opening at one end of the jelly-bag which serves as a mouth. As the waves roll by, the tiny creature draws from them the morsel of lime they contain. This lime forms the bony structure at the end of the drop of jelly. Before dying, the coral polyp gives off an egg, or more correctly speaking a *bud*, for the egg is attached to the mother and only in rare cases floats away.

The bud given off by the parent develops in turn, goes through the same processes as its predecessor, buds in turn, and dies. If the egg happens to float off, it attaches itself to the nearest rock, and there begins another family tree.

The coral polyp requires a temperature of sixty-eight degrees. It grows at a depth of not more than one hundred feet below the surface, and must have clear salt water, and be exposed to the dash of waves—not rough—but brisk. The action of the waves breaks off portions of the coral tree. These falling to the bottom form a sort of trap for shells and other substances. Some portions of the limestone, ground to powder by the waves, forms a cement which finally fastens



FOOT-PRINTS AND RAIN-DROPS.



CORALS.

the whole mass together. This under-water hill continues growing till finally a coral island is formed.

The conditions of temperature, etc., above given, refer only to building polyps. There are other varieties found at various depths and in much colder latitudes.

All through the Pacific may be found charming islands, probably of volcanic origin, surrounded by a low platform of coral, extending far out to sea. The presence of these platforms is indicated by the white breakers rolling over them.

According to *Agassiz*, all the southern part of Florida has been made by coral polyps, and according to the same authority, coral grows at the rate of *one foot in a hundred years.* Judge from this the time it has taken to build two hundred miles of the south coast of Florida.

TESTS.

A piece of limestone put into a strong acid will effervesce.

With the aid of the microscope the *shells* may be seen in chalk.

(Chalk is not found in America.)

Put a bone in strong acid, and the acid will gradually draw all the lime out of the bone, leaving nothing but the cartilaginous structure. Put a bone into the fire and the fire will burn all the cartilage away, leaving only the lime.

CLAY.

Clay is the silicate of alumina. Pure clay is very seldom found; it is generally a mixture of many minerals.

Feldspar, one of the constituents of granite, is a silicate of alumina united with a silicate of potash or soda. The moisture of the atmosphere dissolves the potash or soda, leaving the silicate of alumina or clay.

This clay will, when hardened under conditions of great pressure and heat, change into slate, the particles of clay being held together by some cementing substance, generally a carbonate of lime.

Tyndall says the peculiar cleavage, known as slaty cleavage, has been caused by immense pressure at right angles with the strata. He proved his theory by experimenting with plumbago, beeswax, and the clay itself.

Many geologists say that the mountain chains of the world have been formed by this same lateral pressure, and not by some sudden and violent action of the forces of nature.

What is known as the *jointed structure* in rocks has no doubt been formed by the same pressure, acting at right angles with the plane of deposition.

Industrially, the clays are of great importance, as from them porcelain is made.

LAVA.

The term lava is applied to the liquid matter poured from a volcano during eruption and also to the same when it has hardened into rock.

There are four kinds of lava viz.: *stony*, *glassy*, *scoriaceous*, and *tufaceous*.

When the lava cools slowly it forms stony lava (basalt); if it cools rapidly, glassy lava (obsidian); if it hardens while yet full of gas bubbles it is called scoriaceous lava; hardened volcanic ashes form tufa.

Pumice is another variety of lava.

When examined mineralogically it is found that lava consists of feldspar, augite, and magnetite, in varying proportions.

WATER.

Put a basin of water outside the window on a very cold day and you soon have a cake of ice. Now put the basin over the fire, and in a few minutes you see the *solid* ice becoming again the *liquid* water. Watch a little longer, and you discover the *vapor*—steam rising.

If you let the boiling continue, soon all the water disappears. What has become of it? You saw the visible steam as it rose, but where is it now? It has become invisible vapor, and is dissipated in the atmosphere.

STEAM AND VAPOR.

Steam, or water vapor, has the property of all gases—extreme diffusibility. A quantity of water just sufficient to fill a quart measure will, when converted into steam, fill a vessel one thousand seven hundred times larger.

Man has taken advantage of this immense expanding force of steam, and instead of letting it escape idly in the free air, has confined it within a given space, and, by a system of mechanical arrangements, employs it to turn the ponderous wheel of a steamship, or to direct the delicate needle of a sewing machine.

Besides the familiar steam, there is another form of water vapor. I mean that which is drawn up from the sea by the sun.

In the case of the basin of water we can perceive the cold fluid gradually growing hot, and then rising in the form of steam. When the sun takes the place of the fire, we are not able to note the steps of the process, but the result is precisely the same.

The sun heats the topmost layer of water, and draws it upward through the air. The water is heated and drawn up in such minute particles that we cannot see it ascend as we do the steam from the kettle.

This invisible vapor floats upward through the atmosphere, or is blown north or south by the wind till it enters a colder region, when immediately the hidden sprite becomes visible—the vapor is again turned into water. *Water-dust*, Tyndall calls it, being in fact a mere delicate spray.

It was *heat* that changed the water into vapor, and it is now the sudden chill of the colder atmosphere that has again condensed it into water.

It is the water-dust, floating far above our heads, that forms the beautiful fantastic clouds. As this fine spray becomes gradually more and more chilled, its particles draw closer together. When it becomes too heavy to float any longer through the air, it falls as rain, or hail, or snow.

The greatest evaporation takes place where the heat is greatest—at the Torrid Zone.

There also the fall of rain is greatest, as may be readily understood.

Much of the vapor, however, is blown north or south by the upper air currents, and floats a long way before sufficiently chilled to condense into rain.

If it reaches a cold current, and has to fall through a cold atmosphere, we have snow or hail instead of rain.

Even when the upper current is sufficiently cold to congeal the water into snow or hail, the latter will fall as *rain* if the lower atmosphere has a high temperature This is seen in all tropical countries. No matter how cold it may be on the peaks of Chimborazo or Cotopaxi, no snow falls in the valleys beneath them.

A current of air, laden with moisture, often strikes against the side of a mountain. Instantly the moisture condenses and falls as rain. The dry wind, continuing on its course over the mountain, can give no fertilizing showers. Thus it happens that places on one side of a great land elevation may be clothed in almost perennial verdure, while just over the hills all is dry and barren.

SNOW AND ICE.

Nothing in nature is more exquisitely beautiful than a snowflake. In certain states of the atmosphere it is possible to watch the individual flakes as they float lazily downward, and note the perfection of shape of each. They are all six pointed, but yet what a diversity of appearances! From the mere six-sided disk to the most delicate and fanciful stars. Ice crystals are equally beautiful, and, according to Tyndall, may be sometimes seen in a piece of ice slowly melting on a warm day.

The whiteness of snow is owing to the presence of particles of air imprisoned in the vapor as it condensed.

Ice that has frozen quickly presents this same white appearance. Transparent ice has solidified slowly, and all the air has been *squeezed* out.

This same squeezing out of the air is often performed by a boy making a snowball in thawing weather. The handful of snow he caught up is changed to a lump of ice.

It is a general law in science that cold contracts bodies. If the bodies crystallize, however, on becoming colder, they do not contract, but expand.

This is readily understood if we consider what is meant by crystallizing.

Take a hundred marbles, or a hundred peas, and put them in a shallow box, the bottom of which they just cover. Now attempt to arrange them in six-pointed stars. Will they fit on the bottom of the box? Not at all. Why not? We are obliged to leave spaces between the parts in order to make the stars. Precisely. And that is just what occurs with the water in crystallizing.

It is this same *expanding* power of freezing water that is so fatal to the water pipes on a cold night. As the water begins to freeze it stretches out for more room. Sometimes the pipe will yield a little, thus giving the required space, but often the pressure is too great and the pipe bursts.

ICEBERGS AND GLACIERS.

Far to the north, and far to the south, and on high mountains, there are places where the snow never melts. Year by year the snow falls in immense quantities, but the sun's rays never reach it with sufficient force to transform it into water.

What becomes of it?

It is changed into icebergs and glaciers. I will tell you how:

Each fall of snow presses down the previous fall. By degrees this pressure becomes enormous. I have already told you that the whiteness of snow was owing to the presence of particles of air tangled up with the vapor in freezing. Well, the pressure of the the topmost layers forces all the air out of the bottom layers—changing them to transparent ice. Then, the pressure continuing, this ice is forced out from under the mass of snow, and moves slowly downward. If there is an ocean close by, the moving body of ice approaches its edge, pushes out over it, and then, breaking off, falls into the water and floats—an iceberg. The mountain of ice, being lighter than water, remains about one-eighth above the surface of the ocean. It is carried onward by the current, till, reaching warmer latitudes, it melts.

When there is no sea that the glacier can reach—as in the Alps—it moves steadily downward, pushing, grinding, carrying with irresistible force everything it encounters.

The seemingly solid ice moves precisely as does a river. When a narrow gorge is to be entered, it contracts and pushes forcibly through; when the course is wide and unobstructed, it spreads out and advances slowly.

GLACIER.

Professor Forbes applies the term *viscosity*—semi-fluidity—to this property of a seemingly solid body.

By further experimenting, Tyndall and others discovered that, also like a river, the motion of the glacier is greater at the center than at the sides; greater at the surface than near the bottom.

In the Alps, when the end of the glacier reaches a temperature higher than thirty-two degrees it melts, forming a lake. From the lake a river issues, which directly or indirectly finds its way to the sea.

Thus is the circle ever complete. The sun draws the water from the sea. The water ascends as vapor, is changed to water dust, then cloud, then snow. By pressure the snow is changed to ice, the ice melts, forms a river, and runs back to its mother ocean.

Chemically, water is composed of two gases, oxygen and hydrogen.

The oxygen supports combustion, and also supports life—which is another form of combustion. Combined with carbon, hydrogen is the illuminating gas of our houses and streets. The hydrogen used by the gas companies was at first entirely obtained from coal, but much of it is now obtained from water

AIR.

We live at the bottom of an immense ocean of air—just as fish live in an ocean of water.

Our ocean is deeper, however, being from fifty to one hundred miles, while in its deepest part the water ocean measures no more than five and a half miles.

The water is composed of oxygen and hydrogen chemically united, the air of oxygen and nitrogen simply *mixed together*, just as you might mix sugar and salt in a cup.

But however united, oxygen never neglects the work it has to do. In the water, where it also occurs free, it keeps the fish alive, and in the air it keeps us alive. This busy and important element, the busiest and most important in the world, is an invisible *gas*, quite content to be known by its effects.

Oxygen forms about one-fifth of the atmosphere, the rest being nitrogen, with small quantities of carbonic acid, watery vapor, and ammonia.

Oxygen enables things to burn. It keeps us warm by *burning* the food taken into our bodies. That is how our bodies are kept warm. All the chemical changes that the food undergoes are simply a series of *combustion without flame.*

It is this same oxygen that makes the fire burn. In cases of conflagration, if the day or night happen to be windy, the destruction is proportionately great, because then the supply of oxygen is greater.

The nitrogen, though four times as great in quantity, has no duty to perform except to dilute the oxygen, just as you dilute your coffee with water when it is too strong. We have compared the oxygen to strong coffee, but it would be more correct to compare it to strong wine. For when pure, oxygen is an excitant. It would make the blood rush madly through the veins, burn, kill.

The length of a man's life would depend on the amount he breathed in, and the more he breathed in the shorter time he would live. Here is a very good illustration of the proverb that a man may have too much even of a very good thing.

This element, like the giant in the fairy tale, is continually tearing down and building up again. It has a wonderful affection for metals, and wherever it finds them in the rocks tears them away to make new combinations. But it is not for metals alone that oxygen has affection. There is hardly a substance with which it will not unite, passing freely from one to another, according to the degree of *affinity* it has for each. Thus a perpetual change is kept up. Thus the rocks are disintegrated, and thus they are again made up.

The carbonic acid of the air is obtained from decaying vegetable and animal matter, as well as from the lungs of animals. We breathe it out, glad to have it gone, because it is poisonous to us. It is otherwise with the plant. *That* needs it. It is the food on which it in great part lives.

The ammonia of the air is also used up by the vegetable kingdom.

The height of the air is estimated at from fifty to a hundred miles. This is how it is computed:

Everything burns in oxygen. A meteor falling from Jupiter, say, rushes through space, a mere black mass till it strikes our atmosphere. There it meets the oxygen, and instantly bursts into flame. Two widely separated observers notice the falling body at the same instant. From the angle between the two directions, scientific men compute how high above us the meteor was when first observed, and that distance is the height of the atmosphere.

What keeps the air from flying away from the earth altogether?

The action of a force which just balances the flying off force.

Gravitation is the force that tends to draw all bodies towards the center of the earth, and that force is just sufficient to balance *diffusibility*, the force that tends to spread out gases, to make them fly off into space.

The air near the earth, having to support all the upper layers, is more densely pressed together. This is proved by ascending mountains. At a certain height the air becomes so rare that it is with difficulty we can breathe it.

The *weight* of the air has been ascertained to equal a pressure of fifteen pounds to the square inch. The reason we are not conscious of this pressure is because it presses equally in all directions.

The pressure can be detected by putting the hand over the receiver of an air-pump, and then pumping all the air out of the receiver.

The hand becomes very conscious then of the fifteen pounds pressure.

What makes the wind blow?

The sun is continually heating the air in some part of the earth. Heated air expands, becomes lighter and rises. The colder air rushes in to fill the place left by the heated air, and this rush of the cooler air is wind.

FOSSILS.

A fossil is the remains or evidence of an animal or plant belonging to a former geological epoch.

Sometimes the fossil has been preserved in an almost natural condition. In Siberia, elephants belonging to an extinct species have been found in such a perfect state of preservation that dogs and wolves have fought for their flesh.

In the fossilized wood of the coal measures every stage of preservation may be seen.

There are in the valley of the Connecticut fossil bird tracks. No bird of to-day makes such tracks, but from them the geologist builds up and gives us a picture of the winged creature that some million years ago walked over the soft mud of the valley.

Another mode of preserving the fossil is by petrefaction. Water having silica or some other petrifying substance in solution, first fills up the spaces in the buried plant or animal, and then, as the parts fall away, every particle is replaced by a solid particle of the silica. Thus not only the outward form, but the entire internal structure, even to the delicate tracings of the cell walls, is preserved.

AGES OF THE EARTH.

The history of the earth has been divided into seven ages, each marking the reign of some form of life. They are as follows:

1. Archaean or Eozoic (Dawn of life).
2. Silurian (Age of Mollusks).
3. Devonian (Age of Fishes).
4. Carboniferous (Plants of the Coal Measures).
5. Age of Reptiles.
6. Age of Mammals.
7. Age of Man.

ARCHAEAN OR EOZOIC AGE.

The Archaean rocks are called the oldest of the earth. Yet they form no part of the primary crust, for they are *stratified*, and consequently were deposited in water, being formed from *debris* of older rocks.

The rocks of this age do not differ from those that follow. They are limestones, sandstones, and clays, but all highly *metamorphic*, that is, changed by heat and pressure into marbles, granites and slates.

Beds of iron ore, sometimes a hundred feet thick, are found between the strata, and also immense quantities of graphite.

Now, graphite is a form of coal, and coal is produced from plants, consequently plants of some kind must have existed at that remote time.

SILURIAN AGE.

The life of the Archaean epoch is so obscure that geologists hardly know how to term it. With the Silurian, however, there is no such difficulty. It literally swarms with life. Barrande gives over ten thousand species. The plants, however, appear to have been all seaweeds, but among the animals every type except vertebrates existed. Corals were particularly abundant.

Of course, no plants except seaweed could live during this age, for nearly the entire surface of the globe was under water. Besides, there was very little light. Dense vapors surrounded the planet, so dense that the sun's rays could only faintly penetrate them.

"Corals were very abundant, forming often whole rock-masses, as if they, while living, formed *reefs*. These, if they indicate warm seas, show a great uniformity of temperature, since they are found in all portions of the earth alike."—*Le Conte.*

DEVONIAN AGE.

The *life* of the Devonian Age was different from anything that preceded it. For the first time we have land plants. These plants were not like the plants of to day, though of course our vegetation is derived from them.

The great characteristic of the Devonian is not its plants, however, but its fishes. These, though belonging to the order of the vertebrates, and true fishes, differed greatly from those of the present time. Their nearest living representatives are the sturgeons and the sharks.

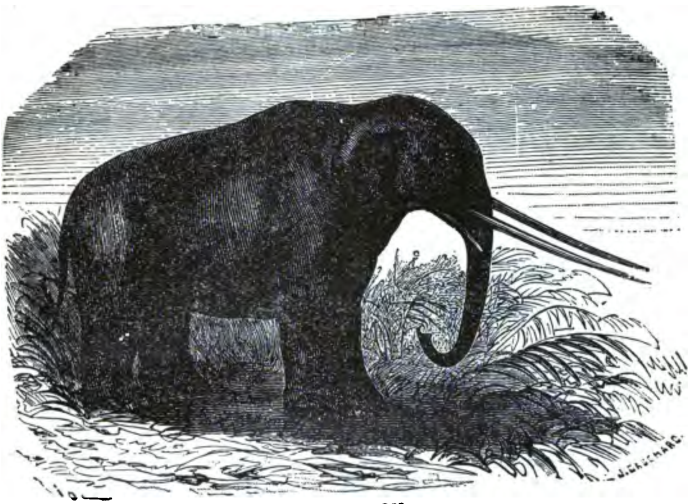
Enormous fishes they were, armed with *teeth* and *coats of mail.*

Hugh Miller speaks of one thirty feet long. Another is mentioned whose *teeth* were two inches long. Many of these monsters were covered with thick, bony scales, forming a perfect armor. The fishes of the present time (*Teleosts*) of course did not exist. They could not exist in the same waters with their fierce relatives. They did not appear in fact till their fierce relatives had nearly died out.

Never before or since were there such fishes as those of the Devonian Age. Covered with scales as hard as bone, and armed with sharp teeth, they were well prepared to make war on one another.

The bony scales, the sharp teeth, and *an imperfect lung,* possessed by some of these fishes, have induced scientists to class them as partly reptilian. No doubt they may be considered the forerunners of the monstrous serpent race that was to come.

"The *Dinichthys* is the largest Devonian fish yet found in America. It measures eighteen feet long and three feet thick. The jawbones, both upper and lower, are bent, the one downward, the other upward, at the extreme end, and extended to form two strong, sharp front teeth. Behind these the jaws are knife-edged, and act like shear-blades. The head and fore part of the body were covered with large protecting plates."—*Newberry.*



MASTODON.

FOSSIL TREES IN COAL MINE.

CARBONIFEROUS AGE.

The coal measures of Nova Scotia are thirteen thousand feet deep; of South Wales, twelve thousand feet; of West Virginia, four thousand five hundred feet, and of Pennsylvania, four thousand feet.

By a coal measure is not meant the depth of coal found in any given locality, but the coal and its accompaniment of other strata.

In every mine there is a regular succession of rocks, consisting generally of sandstone, limestone, coal and iron ore.

The rocks are not always arranged in the order given, but in each coal measure there is a regular succession for that locality.

This fact is very important to the miner, for it enables him to find the coal seam again when it has been lost by a slip or *fault* in the strata.

In the western coal fields of the United States the coal is generally found in horizontal strata, just as, no doubt, it was deposited. Farther east, however, particularly in Pennsylvania, the strata are greatly distorted, often coming up to the surface like metallic veins.

The coal seam is quite insignificant in appearance when compared with its accompanying sandstones, limestones, and iron. Though occasionally a seam fifty feet thick may be found, that is exceptional. A seam eight feet thick is considered good, and one only three feet is worth working.

The coal mines of England are the most productive at present, but scientists say that at the present rate of consumption they will be exhausted in another hundred years.

No estimate of the probable duration of American coal fields has yet been made. They seem inexhaustible.

The era of the coal formation was the era of great trees, just as the preceding one had been the era of great fishes. The great fishes abounded yet in the carboniferous age, but they were not so numerous—the monsters were dying out.

But the vegetation which up to this point had been scanty, consisting of little more than seaweeds, now suddenly became luxuriant. We say it *suddenly* became luxuriant, for so it seems to us; no doubt, however, the change was gradual, but we have lost the early stages.

The trees resembled the ferns and conifers of the present, but were larger, the conifers attaining the height of sixty or seventy feet; the ferns formed a thick underbrush.

The roots of the ancient forest are found bedded in the underclay, and the impressions of the leaves are found in the overlying shales of the mine. The leaves, even to the finest venation, are sometimes preserved in the shale. When the shale is light colored the contrast of the jet black leaves is very fine, resembling beautiful frescoes. Of the trees, all except the root, which is not always changed, and the fine leaves at the summit whose *impression* merely remain, have been changed into coal.

The general theory is that coal has been accumulated at the mouth of rivers; that is, in places subject to the overflow of the river and the occasional incursion of the sea. This explains the clay, and sand, and limestone found interstratified with the coal.

The theory of the coal formation is as follows:

The trees and shrubs grew large and rapidly. Why, will be explained later. They grew at or near the mouth of some great river, which occasionally overflowed the forest or jungle. The trees grew, died, and decayed in the jungle, the work being aided by the water from the river. Next the ground sank gradually, as many parts of the earth are doing now. Then the river flowed uninterruptedly over it, depositing its sands, which form the sandstones of the coal measure After awhile the river was pushed aside and the *sea* flowed over the sandstone, depositing a layer of ground or broken shells, the limestone of the coal measure. Later the land was again upraised, a fresh jungle sprang up, the great trees again appeared, only to go through the same processes of growth and decay. Again the river flowed over it, again the sea rushed in. This was all repeated perhaps a hundred times. The thickness of the coal seam varies as the time the forest held sway varied. We have seams a quarter of an inch in thickness up to those which measure fifty feet.

What length of time do the coal measures represent?

According to Lyell, not less than one million years. This seems astounding, but the scientist has computed carefully, and says, if anything, the time was greater.

It has already been stated that the western coal fields of the United States are nearly or quite horizontal strata. That is, they remain just as deposited, while the more eastern fields are greatly folded. It may now be further stated that the western fields are bituminous, while the eastern are formed of anthracite coal. Now, bituminous coal differs from anthracite only in having its volatile parts driven off by heat. Anthracite, then, is bituminous coal whose volatile parts have been driven off by heat.

Whence came this heat? From the center of the earth? Not at all. The western fields are just as near the center of the earth as are those of Pennsylvania. The heat was generated *mechanically*. That is to say, the immense force that bent and twisted the coal measures of Pennsylvania was sufficient, when changed into heat, to metamorphose the bituminous coal into anthracite. Just as in other cases we have seen heat change common stratified limestone into crystalline marble.

The dead trees had, under pressure of the overlying rocks, undergone the great change into coal. But not by pressure alone, A great amount of heat was also necessary, This heat was generated by the decaying plants. It separated the carbon and hydrogen and oxygen of the plant, and forced these elements into new combinations. Freed from the tissues of the plant, however, they never could return in just the same form. So the plant decayed underground, forming coal.

Then this coal, bituminous, was subjected to the upheaval and pressure, and consequent heat of the close of the carboniferous era, and thus was changed into anthracite.

Why were such immense quantities of coal deposited then, and so little since that time?

There were four causes at work to produce the coal; first, the *temperature* was higher than at present. This is proved by the kinds of plants of the period. Their nearest representatives at the present time are the palms and ferns of the tropical regions—the extreme tropical regions. Second, the *humidity* of the atmosphere was much greater than at present. This is known from the fact that there were no great mountains at the time, and mountains are the great condensers of atmospheric humidity. Where there are no mountains there is very little rainfall, and if the vapor that arises from the sea does not fall in rain it remains suspended in the air, causing great humidity. Next, the temperature must have been nearly, or quite, uniform. This is proved from the fact that we find coal seams far to the north, where no tropical or semi-tropical vegetation can exist at the present time. The fourth condition was the highly carboniferous condition of the atmosphere at that time. According to most recent geologists, it is safe to say that all the carbon found in the coal measures, in plants and in animals, existed at first as carbonic acid floating free in the atmosphere. High temperature, humidity, and an excess of carbonic acid, are favorable to the rapid growth of certain forms of vegetation—such as the plants of the coal period—although unfavorable to animal life, or even to the higher forms of vegetable life. These conditions being widespread, account for the great accumulation of the coal period, and also for its extent. Another fact to be borne in mind is that the coal measures were no sudden formation. Lyell says that *certainly* one million years were taken to form them, and this estimate is more likely to be too small than too great.

"We may therefore picture to ourselves the climate of this period as *warm*, *moist*, *uniform*, *stagnant* (for currents of air are determined by difference of temperature), and *stifling*, from the abundance of carbonic acid. Such physical conditions are extremely favorable to vegetation, but unfavorable to the higher forms of animal life." *Le Conte.*

PETROLEUM.

Wherever fossils are found petroleum is likely to be found. As a matter of fact it *is* found from the lowest Silurian to the uppermost Tertiary. In eastern North America the petroleum and bitumen are found below the coal measures, while in California and in Europe they are much higher—in the *Tertiary*.

Oil, like water, accumulates in limestones and sandstones, because those rocks are likely to contain the fissures necessary to hold the oil.

Like water in artesian wells, the oil is bored for. If it has collected under great pressure, there is enough *gas* generated to force the oil (by elastic pressure) to the surface, sometimes even with great force, making a *spouting* spring. Such force, however, soon becomes exhausted, and the spring becomes a well from which the oil must be pumped. As the source of the oil, unlike the water source, is not continually renewed, the oil well becomes in time exhausted.

The earliest theories concerning petroleum ascribed its origin to coal. That bituminous coal, in its metamorphosis into anthracite, gave off certain volatile parts, and that these volatile parts formed petroleum—bitumen, when hardened.

At present the belief of scientists is somewhat different. It is thought that the petroleum is not an emanation from the coal measure, but is a substance formed independently from vegetation under different conditions. The general supposition is that petroleum is the product of vegetable decomposition in the presence of *sea water*, while the coal seams were formed in presence of *fresh* water, or of alternate fresh and salt water. A very strong point in this explanation is the fact that petroleum is frequently found near salt accumulations in the earth. Like the coals, the oils pass through a regular gradation from oil to bitumen, asphalt, and possibly, as Liebig suggests, to the *diamond.*

According to this authority, the diamond has been formed by the crystallization of pure liquid carbon.

Two hundred thousand square miles of the surface of the United States is underlaid by oil-bearing rocks; thus we may consider the supply of oil as not soon to be exhausted.

As before stated, the great fishes of the Devonian disappeared, but in their place came the *amphibia*—animals able to live in air or water. The amphibia, though quite different from those of the present day, were true amphibia, being furnished with lungs and gills. Many of them were quite reptilian in character, forerunners of the race to follow.

At the end of the coal formation occurred the great upheaval known as the Appalachian revolution; that was the period of the elevation of the great mountain range of the eastern section of our country. This upheaval was not sudden, however, but the gradual effect of the immense horizontal pressure of the rocks. Up to that time the continent had been quite level, the central part somewhat sunken, and the Rocky Mountains yet hardly appearing as more than islands rising out of the shallow, central sea, whose alternate risings and depressions rendered possible the coal formations.

How did the earth look at the close of the Carboniferous Age? Here is what Figuier says:

"The living creation was yet in its infancy. No mammals roamed the woods, no bird had yet spread its wings in the air, nor uttered its song. The profound silence was only broken by the croaking of the frog, or the *dragging* sound of some small muddy reptile moving across the shingly beach."

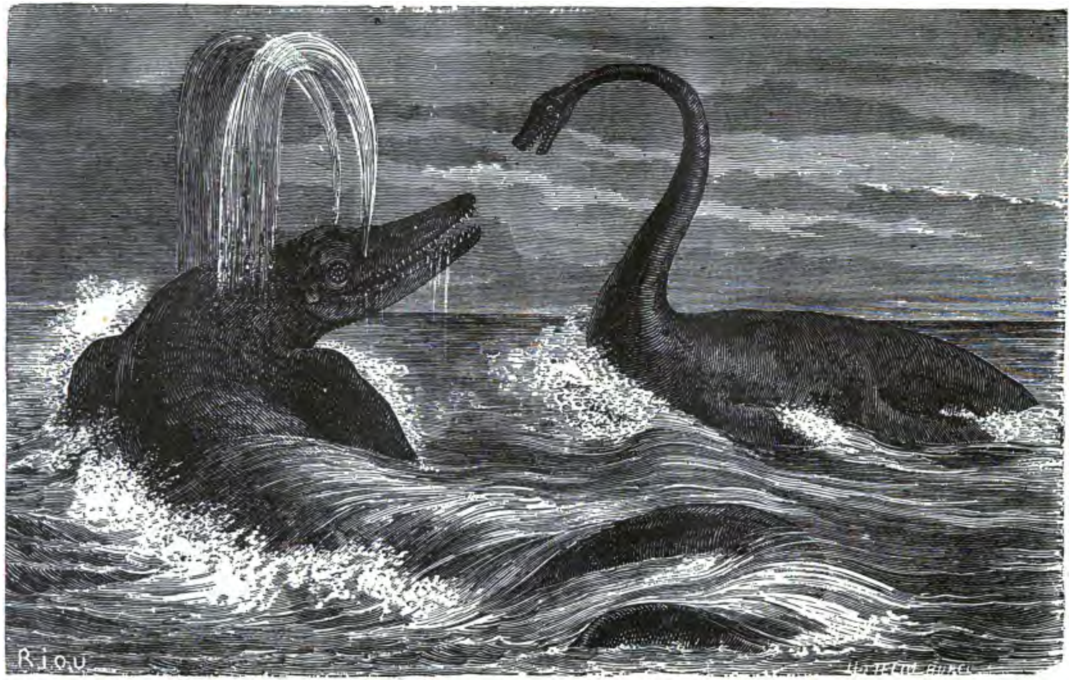
AGE OF REPTILES.

"Never in the history of the earth, before or since, did this class (reptiles) reach so high a point in numbers, variety of form, size, or elevation in the scale of organization." *Le Conte.*

The first thing to be noticed in this period is the gradual disappearance of the great trees of the coal measure. The trees having done their work, laid up great stores of coal and oil for future time, began to dwindle in size, and then new species, one by one, appeared—species approaching those of the present day.

The fishes that flourished during the latter part of the coal measures were half reptilian in character, a sort of intermediate link between true fishes and true reptiles. Now, however, the true reptiles began to appear. Horrible things they would have been for us to see, but luckily we were not there to see them. It was a long time yet before *man* should appear on the scene.

The principal classes were the *labyrinthodonts*, the *saürians*, and the *lacertians*. The labyrinthodonts were so called on account of the intricate formation of their teeth. This class first appeared in the preceding age, but culminated now. These animals had both gills and lungs, were covered with horny scales, and the head armed with horny plates. They were large, often gigantic, in size. The so-called feet were always weak, and in many cases were paddles merely. The fossils of these animals are generally a few fragments of the hardest part of the skeleton and *footprints* that have been found in the hardened clays of the period. Speaking of one of them, Dana says: "We thus learn that there existed in the region about Pottsville a mud flat on the border of a body



ICHTHYOSAURUS AND PLESIOSAURUS.

of water; that the flat was swept by wavelets, leaving ripple marks; that the ripples were still fresh when a large amphibian walked across the place; that a brief shower of rain followed, dotting with its drops the half-dried mud; that the waters again flowed over the flat, making new deposits of detrius, and so buried the records."

The head of one of these monsters was three feet long and two feet wide, and the teeth measured three and a half inches.

The *saurians* were the lords of the age. They ruled not only the sea and the land, but the air as well, for the varieties are described as *swimming*, *walking*, *and flying*.

"The *ichthyosaurus* (fish-saurian) measured from thirty to forty feet; the body thick, the head enormous, the teeth large and sometimes two hundred in number. The animal had a strong tail, was besides furnished with four stout paddles." *Lyell.*

The *plesiosaurus* was a less heavy and powerful animal than the last. It had a turtle-shaped body, and long, snake-like neck. The head was small, and the tail short. The swimming organs were powerful paddles, sometimes seven feet long. The whole length of the animal was from twenty-five to thirty feet.

The *dinosaurs* were the terrors of the land. "They were the most highly organized in structure, and the hugest in size that have ever existed." *Le Conte.*

As the fish saurians combined the characteristics of fishes and reptiles, so the dinosaurs combined those of birds and reptiles. The great point of resemblance was the limb-bone, which, as in birds, was long and *hollow*. They were quadrupeds, and walked freely instead of crawling, like modern reptiles. Many of them had the power of walking on their hind legs alone. Huxley calls them bird-legged.

The *iguanodon* was a huge dinosaur, with habits perhaps like those of the hippopotamus, that is, it wallowed in marshes and fed on the rank grass found there. Its length was from thirty to sixty feet, and its size several times that of the elephant.

The *megalosaur* was carnivorous. Its jaws were very large and armed with knife-like teeth. The animal was at least thirty feet long.

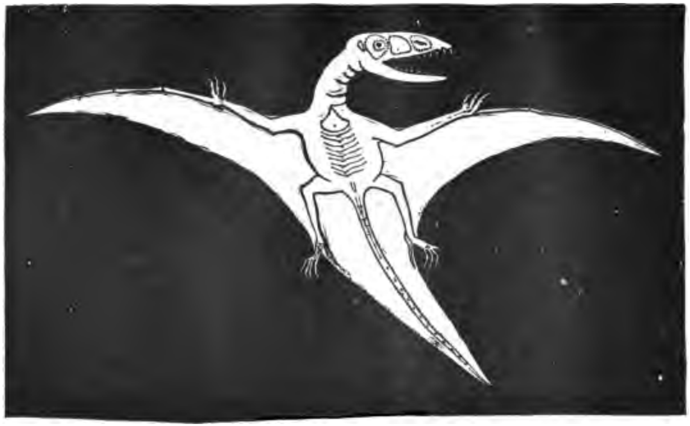
The *ceteosaur*, a herbivorous dinosaur, described by Prof. Phillips, was from fifty to seventy feet long, and stood ten feet high.

The *compsognathus*, described by Huxley, seems more a bird than a reptile. The head is small, the neck long and flexible; while the fore-legs are so short as almost to disappear altogether. Evidently the animal used its hind legs only in walking.

The saurians thus far described were extraordinary, principally on account of their immense size. But the remaining group, *Pterosaurs*, are the most wonderful of which we have any history. The name, pterosaur, means winged reptile, and immediately we say it, visions of all the old legends ever read or heard of appear before the mind. What is a winged reptile but the *fiery dragon* of the nursery tale? But the geologists say they only existed in the *Mesozoic Era*, thousands of years before man was created. How then did the old story-tellers come by them? It would be interesting to know.

But whether St. George and St. Michael ever killed winged serpents or not, the things existed. Here is the description of one that has been restored by Prof. Marsh: "Short, compact body, strong shoulder girdle, long flexible neck, and hollow air-filled bones." All these are bird characteristics, but the animal "has the head, jaws, and teeth of a reptile, and the wings of a bat!" Here was a beauty to fly in at the window of the primitive man! No doubt the geologists are right after all, and no man then existed. The sight of such a monster would have turned him and his just growing family to stone.

Not to be outdone by his brothers of the sea and land,



FLYING REPTILE.

one of these monsters measured twenty feet from tip to tip on wing.

From such awe-inspiring beginnings it is that all the beautiful and musical birds of to-day have been developed. The rocks hold the fossils showing the gradual change.

It was towards the close of the Age of Reptiles that the *chalk formations* began.

Chalk, examined with the microscope, is found to be composed of minute sea-shells. Deep sea dredging brings up a certain ooze, which on examination is found to be identical with the chalk. Thus we know that chalk is now forming at the bottom of deep seas, and we know that wherever chalk is found the sea once rolled. When we consider the slowness with which rocks build up in such a manner, we are lost in trying to reckon how many years were taken to build the "Chalky Cliffs" of England, one thousand feet thick. According to *Lyell*, nearly the whole of Europe was at that time covered by a deep sea.

About the same time the chalk was being formed, modern plants became more numerous, and modern fishes first appeared.

This era in the earth's history marks the elevation of the Rocky Mountains and ranges west of it. At its close it is probable that the great interior sea, which separated the Alleghanies from the Rocky Mountains, slowly or suddenly disappeared. *The bottom of the sea was elevated into dry land.*

SALT.

There are many points of resemblance between the coal measures and the salt measures. Like coal, the salt is found in immense beds often one hundred feet thick, some as high as one thousand feet. The beds of salt, like the coal beds, are interstratified with clays, sands, and limestone. *One* form of limestone, gypsum, is always underlying the salt bed.

There was no particular period of the earth that we might call the *salt age*, for salt is formed in every age, and is forming in this age, too.

Nor is there one particular locality for salt. It is found in all parts of the world. In Canada the beds of pure salt are one hundred feet thick; in New York the salt is obtained by evaporating the water from salt springs.

Near Cracow, in Poland, there are wonderful salt mines. They have been worked for over six hundred years, and are not exhausted.

Speaking of these mines, Dana says:

"These deep subterranean regions are excavated into houses, chapels, and other ornamental forms, the roof being supported by pillars of salt; and when illuminated by lamps and torches they are objects of great splendor."

Salt beds are formed by deposits from water having salt in solution; that is, from sea water. A salt lagoon may have been originally an arm of the sea, which has been cut off from the same. As the imprisoned water cannot flow out, it will disappear by evaporation. The salt being too heavy to pass off with the evaporating water, will be deposited in a layer more or less thick, according to the amount of salt originally held in solution.

There is another substance always in solution in sea water—gypsum. The gypsum being less soluble than salt, it will be deposited earlier, forming a floor, as it were, for the deposition of the salt.

But salt will also be deposited from river water and spring water, there being always a trace in both.

In such cases, however, the lake or sea into which the rivers flow loses its surplus waters, not by *outlets*, but by evaporation, and the salt forms a layer.

"The Dead Sea and the Caspian have become salt from this excess of evaporation over supply."—*Murchison.*

On the other hand, Lake Champlain, which was once an isolated arm of the sea—consequently salt-depositing—has, by finding a way to the ocean through Sorel River, become a fresh water lake.

There is a region at the mouth of the Indus called the *Runn of Cutch*, which is part of the year under water and part above. This singular region comprises about seven thousand square miles. During the dry season it is incrusted with salt which has been left by the evaporation of the water. Year by year the successive layers of salt are thrown down one upon the other. "The supply of brine from the ocean is as inexhaustible as the supply of heat from the sun. The only assumption required to enable us to explain the great thickness of salt in such an area is the continuance for an indefinite period of a subsiding movement, the country preserving all the time a general approach to horizontality." *Lyell.*

AGE OF MAMMALS.

In this age the earth began to assume a more modern aspect. Whales and sharks abound in the seas, mammals roam the woods, and birds fly through the air. It is true those forms of life were not precisely such as we see now, but the resemblance is sufficiently close to enable us to prove how closely related they were. The plants, too, were quite like the modern, but are not found in the same parts of the earth. *Palms* grew at that time in Iceland, Lapland, and other extreme northern parts of the earth. The fact that these tropical—or semi-tropical—plants grew in all parts of the earth indicates that the climate was not only warmer, but more uniform.

The age of reptiles has gone by, *birds* and *mammals* appear on the scene.

Marsupials had already come, but it was not till the great reptiles had died out, or were dying, that true mammals appeared.

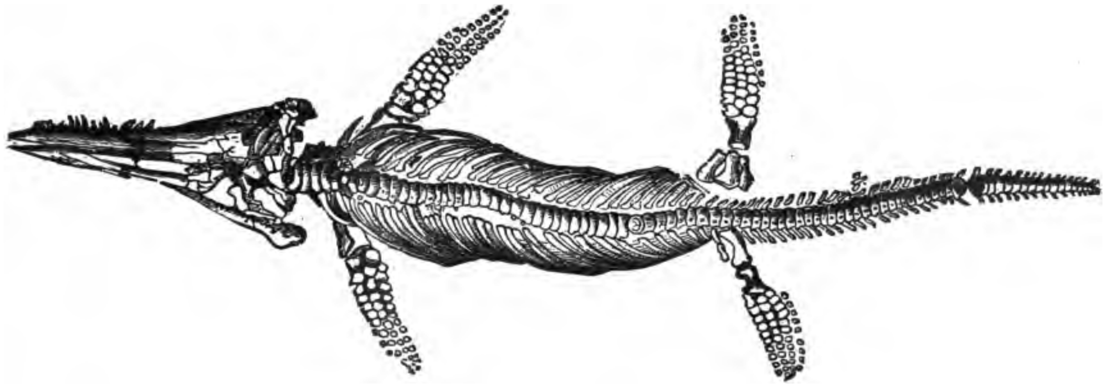
One characteristic of the first mammals is that they were herbivorous (plant-eating). They belonged to the order of *pachyderms* (thick-skinned), an order now represented by the elephant.

The lime quarries about Paris have yielded splendid fossil specimens of these animals. At the foot of the Himalayas, in India, they are also found in great abundance.

One, the *dinothere*, combined the characteristic of several animals: the elephant, rhinoceros, tapir, and marsupial.

It was a huge animal, whose head—five feet long—was armed with two tusk-like teeth and a proboscis.

The *sivathere* was a four-horned antelope as large as an elephant.



ICHTHYOSAURUS. (Skeleton.)

Mastodons—huge beasts—the direct ancestors, so to speak, of our elephants, now appear.

Among these inoffensive plant-eaters the terrible sabre-toothed tiger is occasionally found.

Right here in the midst of this flourishing mammalian life occurred the overwhelming catastrophe known as the *Glacial Epoch*—the Ice Epoch—when the warm, uniform climate gradually changed to one of intense cold. When in our country, from the North Pole almost to the Gulf of Mexico, the land became covered with a sheet of ice; when all plant life within its reach died out, and only such animals escaped as were able to find their way to the warmer regions near the equator. In Europe the destruction caused by the Ice King was equally overwhelming.

THE GLACIAL EPOCH.

Various theories are given to account for this great change of climate. The one usually adopted is that the northern hemisphere, as far south as the fortieth degree, became gradually elevated, till it stood from one thousand to two thousand feet above the present sea-level. Then this immense tract of land became slowly covered with an ice sheet creeping down from the North Pole. The depth of the ice has been estimated at from three thousand to six thousand feet. The ice moved downward as a huge glacier, or more probably several huge glaciers, striating* rocks gouging out valleys, and scattering the *debris* collected in its course in the form of moraines or boulders.

According to Hilyard, one of these glaciers extended down the valley of the Mississippi to the Gulf.

What desolation everywhere! Just before, we found the earth assuming a pleasant appearance. The frightful fishes and reptiles had gone, and though the huge mammals still remained, they were generally mild, plant-eating brutes, only remarkable on account of their size.

We know that the forests must have worn a very modern look, from the trees and shrubs of the period, and that they were enlivened by the songs of the birds.

And now what an awful change! Step by step the frightened denizens of the woods must have seen the relentless glaciers approach. Day by day, those who could must have sought safety in flight. But they ran bewildered, and the long fingers of the Ice King clutched many of them before a place of safety was reached, and so we find their bones scattered all over the strata that the glaciers covered.

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*Scratching.

It is a question how long this ice sheet remained, but slowly, slowly, having done all the evil in its power, it finally began to retreat. To melt would perhaps be more correct, for the geologists say that the continent sank again, not merely to its old level, but from five hundred to one thousand feet below what it is now. This subsidence, of course, caused great overflows. The time became one of *inland seas.* The Hudson River glacier, and the Susquehanna, as well as the great ice tongue in the Mississippi. melted away. But everywhere they left unmistakable evidence of their having been.

This remembrance of the glaciers we find in clays, sand, and gravel, under the general name *drift* This drift is found overlying, loosely, rocks of a different kind, showing plainly that it is not the result of decomposition, but that it has been brought there by some powerful agency. Besides, the immense boulders, rocks strange to the locality show that the power that brought them was irresistible.

Besides the *drift*, scientists have the evidence of the striating or scratching of the surface rocks. This scratching has been done by the grinding force of the boulders, dragged over strata while they were imprisoned in the moving sheet of ice.

All the effects of glacier motion which Tyndall and others have so well studied in Switzerland are found here repeated.

The evidence of the elevation of the continent during the Ice Age is found in old sea margins.

"About Boston the old beaches are from seventy-five to one hundred feet higher than at present; on the Gulf of St. Lawrence they are four hundred and seventy feet, and in Arctic regions one thousand feet higher." *Dana.*

Along the shores of Lake Champlain the skeleton of a whale has been found.

In Europe the ice sheet covered not only Scandinavia, but all of Scotland and the northern part of England.

When the land subsided it went down, as in America, far below its present level. The British Isles disappeared, or were only visible at their highest points.

Here we resume the description of the mammals, interrupted by the Ice Period.

The remains of animals found in the soil, over which the ice had extended, and in caves into which those animals huddled or were drifted, show the largest mammals yet found.

The *mammoth*, an animal whose nearest modern representative is the elephant, must have roamed over all parts of Europe and over the northern part of North America.

The mammoth was twice the size of the elephant.

It was covered with *wool*, and in parts with long hair. Its thick coat fitted the animal for cold climates, and according to some geologists, renders it unnecessary to suppose that the warm climate extended to Siberia (where the remains have been found). But if the climate were not warm enough to produce luxuriant vegetation, on what could such huge plant-eaters live? Notwithstanding the fur coat of the mammoth, the evidence points to a tropical or semi-tropical climate for Siberia in the period following the Ice Age.

The fauna of England was also remarkable.

There are found the remains of a tiger larger than any known to-day. The mammoth is found, as also the rhinoceros, the hippopotamus, the great Irish elk, oxen, the horse, and the deer.

In America everything seems to have been on the same grand scale. We had gigantic horses, gigantic stags, and a beaver five feet long. We also had lions and bears.

Here the large plant-eaters are generally found buried in marshes, where the animal had probably ventured in search of food, and from which he had not been able to escape.

"One magnificent specimen was found in a marsh near Newburg, New York, with its legs bent under the body and its head thrown up, evidently in the very position in which it

MAMMOTH. (Found in Siberia.)

SNOW CRYSTALS.

mired. The teeth were still filled with the half-chewed remnants of its food, which consisted of twigs of spruce, fir, and other trees; and within the ribs, in the place where the stomach had been, a large quantity of similar material was found." *Le Conte.*

This was the largest land mammal ever known. It was twelve to thirteen feet high, and twenty-five feet long. This animal ranged from the Arctic regions to the Gulf of Mexico.

The *megatherium*, an animal allied to the sloth, but of gigantic size, inhabited South America and the southern part of North America.

It was larger than the rhinoceros, but of clumsy structure. It is supposed that it used its hind legs and tail to support the immense body while tearing down the branches on which it fed. The fore legs were more like arms, being free-moving, and terminating in hands a yard long.

In Australia the same species existed then that we find there at the present time.

The ancients, however, were giants in comparison with their descendants.

A *kangaroo* is described which was as large as a rhinoceros. Prof. Owen speaks of another marsupial as large as a bullock, having teeth like a lion. He calls it the *pouched lion.*

In considering the various forms of life that have successively appeared on the earth, we are often lost in wonder at the apparent suddenness of the change as well as at the great dissimilarity of succeeding forms.

A closer study, however, shows us that the change has not been sudden, and in considering the modifications in life forms, that we have overlooked the connecting links.

The truth is that all changes have been extremely slow, and that the forms of life have so merged one into the other that the scientists are often puzzled where to place a plant or an animal in the scale, the organism having characteristics that ally it with those above and those below it. Then, too, *time* is of no account in geological researches.

We must get rid of our nursery notions of the duration of the earth in order to fully grasp its history as told by the rocks. Computing the time required to form the crust of the earth by the rate at which sediment now deposits, it would, according to Le Conte, require thirty millions of years to bring the outside to its present thickness.

Nature works slowly. It took a million years to lay down the coal measures alone.

Then, in describing the animal life of each age, it must be remembered that the form of life from which the age takes its name did not *begin* in that age, but in the preceding.

Thus, though the Devonian is called the Age of Fishes, there were some fishes in Silurian times. Small, however, and insignificant, giving little promise of what they were destined to be in the next age.

So when the reptiles came they were not at first true reptiles, but amphibians, a link between the fish and reptile. The first birds had teeth, and the first mammals were marsupials.

The reason of the gigantic size attained by all orders except man has never been explained. We are compensated, however, by knowing that in all these monsters the *brain* was relatively smaller than in their living representatives.

MAN.

The geologists have been able to trace man as far back as the Ice Age. That is, he is unmistakably found just after the glacial period, and some say they find traces of him before it.

The question is unsettled. But, whenever man may have appeared first on the scene, he has certainly passed through all stages of progress from savagism to civilization.

The reign of man has been divided into three epochs, namely, the Stone Age, the Bronze Age, and the Iron Age.

In the Stone Age we find no indication of agriculture, nor are domestic animals supposed to have been known to the human species. The savage lived just as savages do to-day, by *killing* his food with what implements came to hand. The implement was generally a rude stone, or piece of rock having, accidentally perhaps, a point. His remains are found in caverns with those of wild beasts.

He may have been killed by the beasts, and dragged into the cavern to be devoured; or he with them, for in a common danger we forget old animosities, may have fled into the cave with the beasts. They may have sought safety together in some awful cataclysm of nature.

Later on the stone weapons are found polished, and the dog and horse are associated with the man.

This marks the first step in civilization.

These remains, however, are all found in caves; man is yet too savage to know how to make a dwelling place for himself. While still a cave dweller he learns to catch the finny inhabitants of the deep. We know this by the stone fish-hooks found near him. The use of fire is known, for heaps of ashes and cinders lie near the cave.

Unfortunately, we cannot trace this development through its successive steps up to the present time. The next trace reveals a race so far in advance of the first that it is difficult to conceive they are descendants one of the other.

These are the so-called lake dwellers of the Bronze Age.

These people have been found in the lake regions of Switzerland, and possessed the strange characteristic of wishing to have their dwellings over the water. Their houses were built on piles out in the lakes, and connected by bridges with the land. What was the origin of this strange custom no one seems even able to guess. The dwellings are now under water, but by means of dredging, many interesting discoveries have been made.

The instruments are now bronze, and are meant for agriculture as well as for the chase.

The savage is becoming domesticated. He has the ox, the sheep and the goat associated with him, as well as the dog and horse. He has learned to till the soil, for wheat, barley, and some fruits, are found, as well as the farming implements.

Thus, though the record is far from complete, we are able to trace man from the lowest savage state, killing with a stone, and living on the beasts he had the strength or the cunning to capture, to the savage who had learned to catch fish with a stone hook, to the savage who had learned the use of fire—as the ashes and cinders testify, to the savage who wished to mark an event, and did so by calling other savages to join him in a feast—as the immense heaps of empty shells show, to the man—no more a savage—who had learned to make bronze instruments, to cultivate the soil, to domesticate useful animals, and to build himself a house.

The next step brings us to the *Iron Age* and Historic Times.

"We have seen that the earliest men yet discovered in Europe or America, though low in the scale of civilization,

were distinctively and perfectly human, as much so as any race now living; and were not in any sense a connecting link between man and the ape. Nevertheless, we must not forget that the cradle of mankind was probably in Asia. Man came to Europe and America by migration. The intermediate link, if there be any such, must be looked for in Asia."
Le Conte.

CLASSIFICATION OF ROCKS.

Diorite.—Dark, greenish gray rock, composed of *feldspar* and *hornblende*.

Granite.—Composed of *quartz*, *feldspar* and *mica*.

Gneiss.—Has the same composition as *granite*, but is stratified (arranged in layers).

Schist.—This is a term used to distinguish the *structure* of the rock, not the minerals composing it. Any rock having an imperfect cleavage may come under this head. As a consequence of this we have *mica-schist*, *hornblende-schist*, *clay-schist*, etc.

Marble.—The ordinary stratified limestone subjected to immense heat and pressure becomes changed to the compact crystalline marble. In some cases traces of the original stratification may be seen, but in the best marbles it is entirely obliterated.

Orthoclase and *plagioclase* are the varieties of *feldspar*.

Syenite resembles granite.

Slate.—Hardened clay. The clay has been formed from the decomposition of other rocks, generally feldspar. *Kaolin*, or common clay, is a white mineral when pure, but is seldom found in that state.

Sandstone.—Essentially quartz which has been deposited in fine grains in water. These grains have been consolidated by a cement of lime or of an oxide of iron. In the latter case the rock is known at *red sandstone*.

Rhyolite, trachyte, pumice, obsidian, basalt, and scoriae, are all forms of *lava*.

Lava consists essentially of feldspar, augite, and magnetite. The different varieties arise either from varying quantities of the constituent minerals, or from difference in way of cooling. When cooled rapidly, the lava forms *obsidian* (glassy lava);

if it cools slowly, it crystallizes and forms *basalt* (stony lava); if it hardens while full of gas bubbles it forms *volcanic cinders* (scoriaceous lava); volcanic ashes deposited in water and hardened forms *tufa*.